Fermilab

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POWER SPOOL TEST

TSH-002

SPTF #19

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INTRODUCTION

The data presented in this Technical Memo will pertain to the operating characteristics of Power Spool TSH-002. This spool had a large number of thermometers built into it. These thermometers monitored most of the thermal characteristics of the 5000 A American Magnetics, Inc. vapor-cooled leads used in this power spool. Operating conditions, such as peak temperatures, ramp and dc lead cooling gas flow requirements, voltage as an indicator of stable conditions (ac and dc) and general voltage characteristics (i.e., amount of ice formed outside of leads vs high-pot voltage) were measured and observed. It was found that previous operating conditions of the power leads influenced the temperature gradients of the leads in certain cases.

EXPERIMENTAL SET-UP AND PROCEDURE

Figure 1 shows the block diagram of Spool Piece Test Facility Run #19, in which the operating characteristics for Power Spool TSH-002 were measured. As shown in Figure 1, the power spool was placed in the middle of a spool string to modify or remove any end effects due to the B-12 feed can and/or the turn around box. Polaroid pictures of the extent of frosting of the power leads in the various run conditions were taken.

The helium gas flow used to cool the leads was routed through a copper coil and heated to room temperature (sometimes excessive heating resulted in flow errors) to set the flow rate. The exit gas temperature was measured under foam insulation, which was located several feet (~3') from the heating coil. The power and water diagrams for Power Spool TSH-002 are shown in Figure 2. Problems that occurred during the power spool test were mainly due to our inability to keep the cooling water of the power supply cold enough. We installed special cooling blocks between the power leads and the top flags of the AMI leads to try to thermally isolate them from the lead flags. This procedure was satisfactory in most of the operating modes. It removed heat during the dc run and acted as a heat source during the zero current and ac current ramps, therefore minimizing the frost build-up, but never quite removing it entirely.

The thermometry on the AMI power leads is shown in Figure 3. These units were high-potted when they were put in place, but were not high-potted again until the end of the tests. All thermometers worked with the exception of the one in position "E". This thermometer read low absolutely, but seemed to be accurate differentially (i.e., using thermometer "B" as reference).

The heat loads were measured in two different regimes, gas and liquid; first the liquid helium operating mode using 18 g/sec liquid flow rate, relying on the ring thermometers and the inlet pump venturi for the operational parameters. Then identical run conditions were set up for the string just above 5K (totally helium gas) with the flow measured by a gas meter at room temperature. This was done for four different sets of run conditions and then cross-correlated to check the load results. The standard spool's losses were then checked against those obtained in previous runs to have another independent cross-check. A standard SPTF Run sequence was followed before the power spool tests were done, therefor the system had been in liquid helium for a day and a half before the special power tests were made. This extended period at operating temperature seemed to make the system very stable and easy to establish repeatable operating conditions.

The thermometers used in the elevated temperature range 20K to 350K were linear thermometers (strain gauge type). Carbon resistors (calibrated) were used as the liquid helium monitors with the glassy-carbon resistors used for the precision temperature difference monitors in the standard insert ring utilized in the SPTF Run heat load determinations.

DATA SUMMARIES

These data were obtained from SPTF Run #19 and previous SPTF Runs (reflected in the error bars).

TABLE I

	LOAD*
TSA-	4.5±0.5 watts
TSB-	6.5±0.5 watts
TSC-	6 ±0.5 watts
TSD-	8.5±0.5 watts
TSE-	6 ±0.5 watts
TSF-	8 ±0.5 watts

*This is with coil lead tower flow of 32 cfh helium (STP).

TABLE II

SUMMARY OF VAPOR AND LIQUID TEST ON SPTF #19

Load of SPTF #19 = 29±1 watt exclusive of TSH-002.
(All loads determined with lead tower flows of 32 cfh helium.)

Helium Gas Outlet Temp. °K AMI 5000 A Lead	Helium Gas Flow Rate (cfh STP)	Load of String (watts)	Load of TSH-002 (watts)
273	160	41±2	12±2
280	133	45±3	16±2
288	107	51±1.0	22±2
292	67	72±2.1	43±2
for comparison use TSA ~4.5±.5 watts			
	188	38±2	9±2

Note there was a slight leak around the seal to the AMI 5000 A leads. Estimate error +10→15%.

TABLE III

SUMMARY OF LIQUID 3500 A dc TEST

Helium Gas Outlet Temp. °K	Helium Gas Flow Rate (cfh STP)	3500 A Load (watts)	Addition Load Due to "I" (watts)	Temp.(°K) "L" Liquid Flag	Temp.(°K) "D" #2$ Vapor Lead	Voltage/AMI Lead Pair mV	Time to Runaway (min)
291	133	80±2	35±1.4	6.9±.1	211	280	8 (unstable)
298	160	63±2	22±1.4	5.3±.1	141	175	15 (unstable)
290	188	53±2	15±1.4	4.1±.1	108	85	48 (stable)

A 5000 A dc run had been planned, but due to excessive cooling water temperatures the system was unable to hold 5000 A dc. The water temperature exceeded 75°C during the 3500 A dc run, causing various failures of room temperature components.

TABLE IV

SUMMARY OF LIQUID 3500 A RAMP CYCLE TEST DATA

The cycle used was 20 sec to full current, 5 sec flat top, 20 sec ramp back to zero, and then 15 sec dead time. This sequence was repeated every minute. The temperatures were stable by the second cycle.

Helium Gas Outlet Temp. °K	Helium Gas Flow Rate (cfh STP)	3500 A Ramp Load (watts)	Additional Load Due to Ramp (watts)	Temp. (°K)* "L", Var. § Liquid Flat	Temp. (°K)* "D", Var. § 3/4 Vapor Lead	Voltage/Lead Pair mV
285	107	61.2±2	10.2±1.4	5.1,±.1	215,±8	110
283	133	51.0±2	6 ±2	4.4, none	194, none	75
273	160	47.6±2	6.6±2	4.4, none	139, none	75
271	188	41	3 ±2	- , -	- , -	75

*The second number stands for the variation in temperature detected during the cycle.

TABLE V

SUMMARY OF LIQUID He 5000 A RAMP CYCLE TEST DATA

The ramp cycle used was the same as that in Table IV, except full current was 5000 A. The 5000 A temperature gradients were larger because we had to set at zero current for a few hours while we worked on the Transrex water supply. The lead (AMI) therefore started out colder than when we cycled from 3500 A dc and immediately started the 3500 A ramp tests. There were at least 15 cycles completed for each data point.

Helium Gas Outlet Temp. °K	Helium Gas Flow Rate (cfh STP)	5000 A Ramp Load (watts)	Additional Load Due to Ramp (watts)	Temp. (°K) "L", Var. § Liquid Flag	Temp. (°K) "D", Var. § 3/4 Vapor Lead	Voltage/Lead Pair mV
281	133	51±2	6±1.4	5.0,±.2	151,±8	190
273	160	44±2	3±1.4	4.7,±.1	136,±4	120
273	188	41±2	3±1.4	4.7,±none	133,±none	110

Lead Temperature Profiles

Thermometer Positions
(See Figure 4 for Postion Code)

Run Condition		A	B	C	D	E
Flow He cfh	Current AMI Leads A	Outlet He (K) Gas	3/4 Lead "A"	1/2 Lead "B"	1/4 Lead "C"	Liquid He Flag
67	0	292	163	111	92	6.5
107	0	288	122	99	86	5.0
133	0	280	111	96	83	4.9
160	0	273	95	81	69	4.9
133	3500 A dc	298	211	133	98	6.9
160	"	298	141	106	90	5.3
188	"	290	108	95	84	4.9
107	3500 A Ramp	-	215	185	167	5.1
133	"	-	194	175	160	4.8
160	"	-	139	124	112	4.9
188	"	-	-	-	-	4.9
133	5000 A Ramp	-	151	129	115	5.1
160	"	-	136	120	107	4.9
188	"	-	133	121	110	4.9

The only explanation that is offered for the higher temperatures on the 3500 ramp data than on the 5000 A ramps of the lower portion of the vapor lead, is the previous run conditions, namely 3500 A dc immediately before 3500 A ramp and the long cooling period at zero current before the 5000 A ramp test was started.

COMMENTS

The data presented here seem to cross-check fairly logically with previous spool piece data where overlaps exist. The liquid and vapor data seem to give reasonable agreement (±2 watts). The losses could be higher by about 10→15% (no correction made for the volume of gas leaking through the lead seals).

TSH-002 high-potted after the tests in liquid in excess of 2.1 kV (a ceiling set for it). Therefore, electrically TSH-002 seems good.

DDQ-1 correction package was qualified for the operation at 50 A for all polarity configurations with the outside dipole operating at 55 A/turn.

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ENGINEERING NOTE

SECTION | PROJECT | SERIAL-CATEGORY | PAGE

NAME: A. D. McINTURFF
DATE: May 1982
REVISION DATE:

SUBJECT: Block Diagram of Run #19

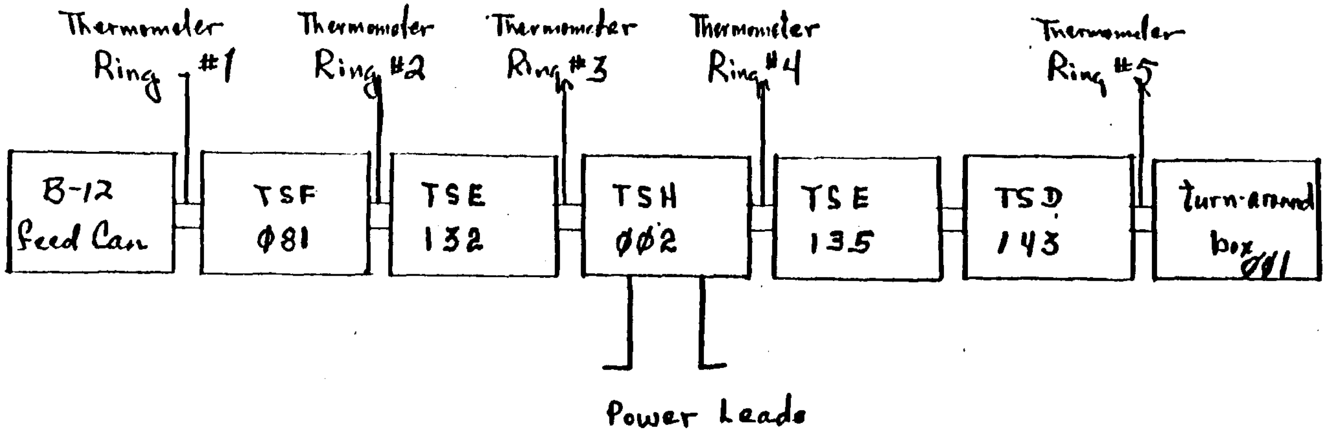

Figure #1

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ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT: Water + Power flow TSH$\phi\phi$2

NAME: A. McInturff

DATE: May 1982

REVISION DATE

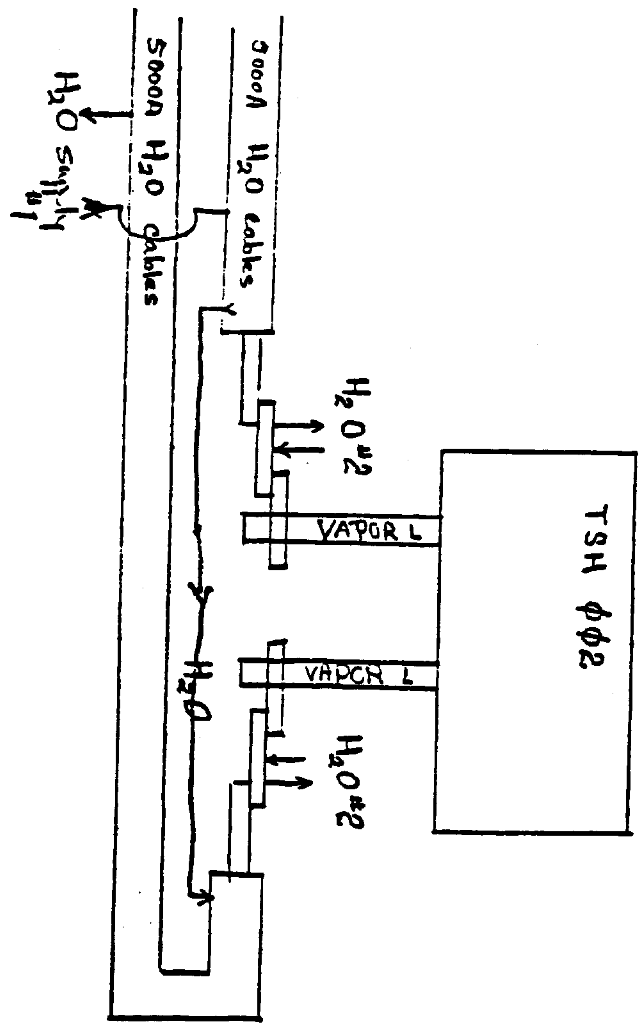
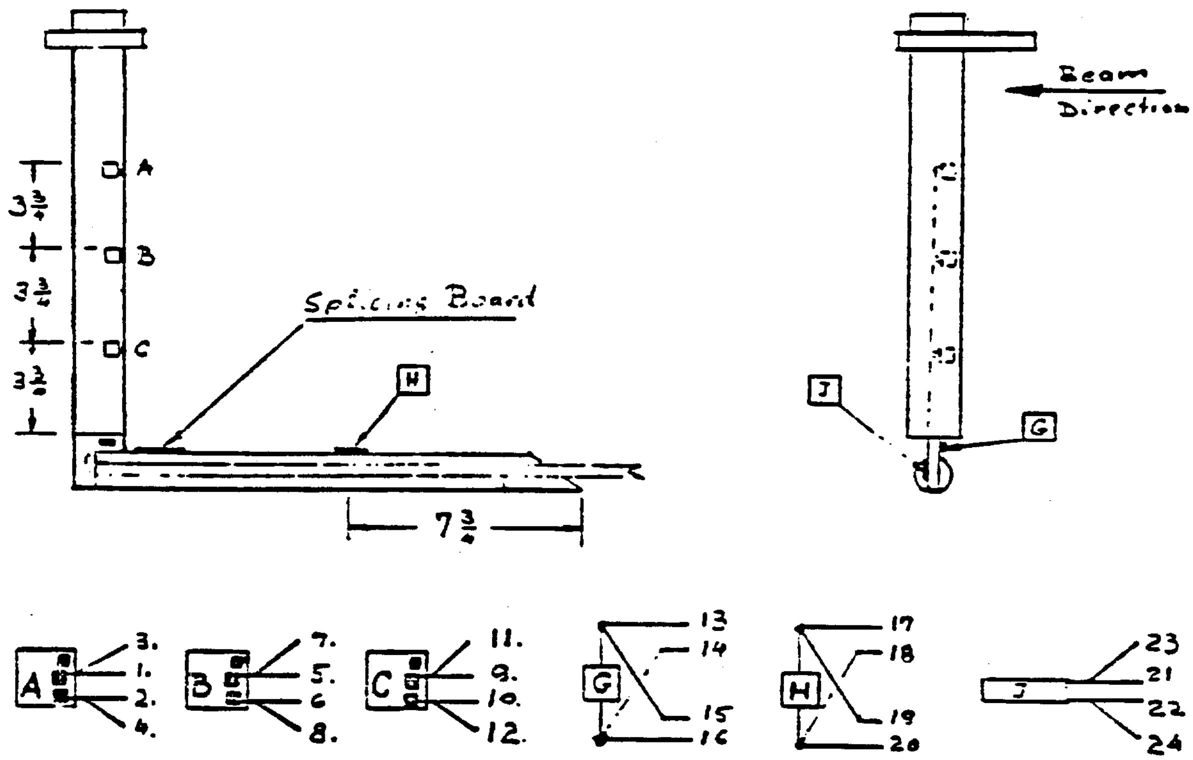


Figure #2

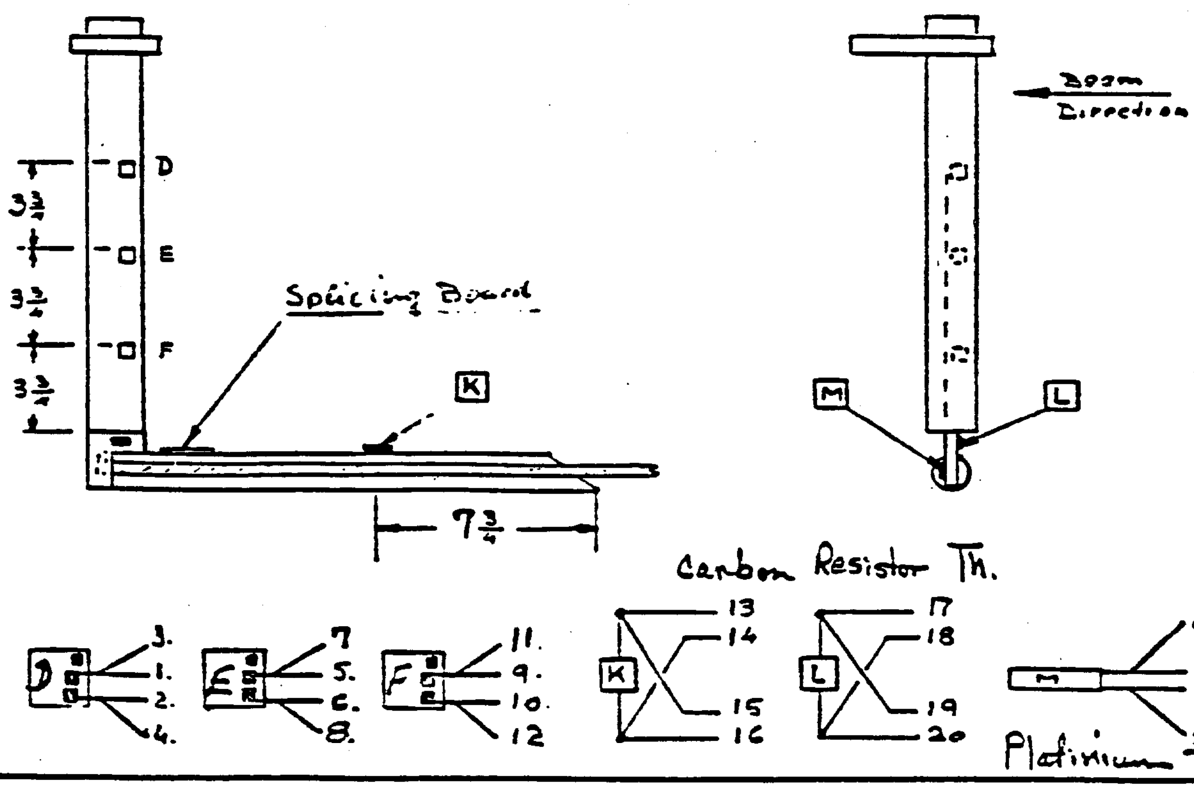
THERMOMETER Schematics on 5000 Amp. Power Feeds.	TM-1114
	Spool No.: TS-H-002

U.S. Power Feed.



figure# 3

D. S. Power Feed



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SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT: Table Temperature Code

NAME: A. McInturff

DATE: May 1982

REVISION DATE:

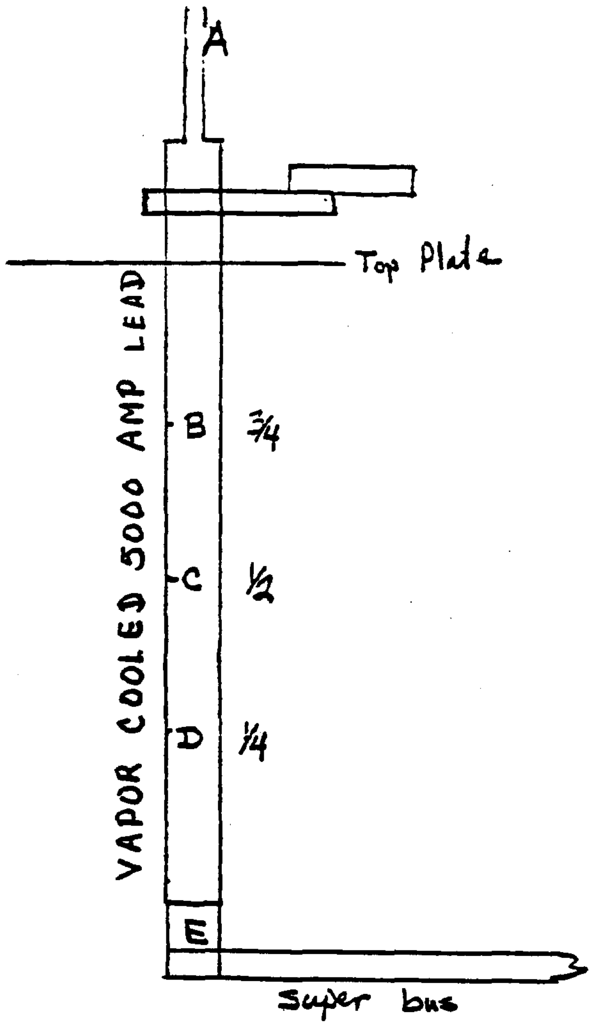

figure #4